66

מדינת ישראל
STATE OF ISRAEL

Ministry of Justice
Patent Office

IL04/714

משרד המשפטים
לשכת הפטנטים

This is to certify that
annexed hereto is a true
copy of the documents as
originally deposited with
the patent application
particulars of which are
specified on the first page
of the annex.

זאת לתעודה כי
רצופים בזה העתקים
נכונים של המסמכים
שהופקדו לכתחילה
עם הבקשה לפטנט
לפי הפרטים הרשומים
בעמוד הראשון של
הנספח.

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN
COMPLIANCE WITH
RULE 17.1(a) OR (b)

This 3 0 -08- 2004
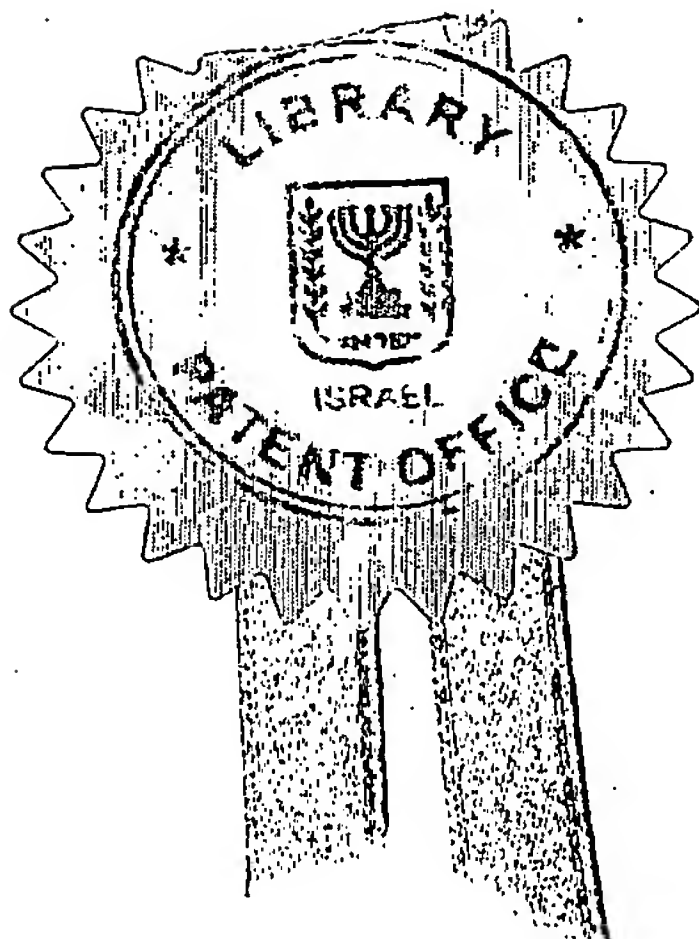
רשם הפטנטים
Commissioner of Patents

נתאשר
Certified

לשימוש הלשכה
For Office Use

מספר: Number	בקשה לפטנט
157344	**Application for Patent**

תאריך:
Date

11-08-2003

הוקדם/נדחה Ante/Post-dated

אני, (שם המבקש, מענו – ולגבי גוף מאוגד – מקום התאגדותו)
I (Name and address of applicant, and, in case of a body corporate, place of incorporation)

Opgal Ltd.
P.O. Box 462
Industry Zone
20 101 Carmiel

אופגל בע"מ
ת.ד. 462
אזור תעשייה
כרמיאל 20 101

Inventor/s:

:המציא/ים

בעל אמצאה מכח __הדין__ ששמה הוא:

Owner, by virtue of **Operation of Law** , the title of which is:

מקור טמפרטורה השוואתי פנימי ופילטר MTF אינברסי לרדיומטריה

(בעברית)
(Hebrew)

INTERNAL TEMPERATURE REFERENCE SOURCE AND MTF INVERSE FILTER FOR RADIOMETRY

(באנגלית)
(English)

hereby apply for a patent to be granted to me in respect thereof.

מבקש בזאת כי ינתן לי עליה פטנט.

*בקשת חלוקה- Application for Division	*בקשת פטנט מוסף- Application for Patent of Addition	*דרישת דין קדימה Priority Claim		
מבקשת פטנט from Application	*לבקשה/לפטנט for Patent/Appl.	מספר/סימן Number/Mark	תאריך Date	מדינת האיגוד Convention Country
No._____ מס' dated_____ מיום	No._____ מס' dated_____ מיום			

*ייפוי כח: כללי/ מיוחד הצורף בזה/ עוד יוגש
P.O.A.: ~~general~~ / specific – ~~attached~~/ to be filed later
Has been filed in case _____ הוגש בענין

Address for Service in Israel המען למסירת הודעות ומסמכים בישראל

G.E. Ehrlich (1995) Ltd.
11 Menachem Begin Street
52 521 Ramat Gan

ג'י. אי. ארליך (1995) בע"מ
רחוב מנחם בגין 11
רמת גן 52 521

חתימת המבקש
Signature of Applicant

היום	11	בחודש	אוגוסט	שנת	2003

This __11__ of __August 2003__

For the Applicant
Attorney Docket No.: 26373

לשימוש הלשכה
For Office Use

מקור טמפרטורה השוואתי פנימי ופילטר MTF אינברסי לרדיומטריה

INTERNAL TEMPERATURE REFERENCE SOURCE AND MTF INVERSE
FILTER FOR RADIOMETRY

Internal temperature reference source and MTF inverse filter for radiometry

1. 1. There are several main obstacles related to building an imaging radiometer especially when the instrument is based on uncooled microbolometer detector array:

   a. a. Usually the microbolometer detector does not contain any radiation shield; therefore, it exchanges energy through a solid angle of 2π radians. Most of the energy exchanged is between the detector and the internal camera parts. Only a very small fraction (usually about 10%) of the energy exchanged by the detector comes from the scenery. A very small change in temperature of the internal camera parts produces a huge change of the detector output signal.

   b. b. It is well known that any camera has a finite spatial response. Two black bodies that have the same temperature, but differ in size, produce different video signals at the detector output.

2. 2. This disclosure describes the solutions developed by OPGAL to overcome the major obstacles described above:

   a. a. In order to obtain a stable temperature measurement, a temperature reference source has to be used. OPGAL's solution is to use an _internal_ temperature reference source. The mechanical flag used for updating the non-uniformity correction (NUC) matrices is also used as a temperature reference source. The flag is periodically inserted between the detector and the optics in order to update the NUC tables. Each time this process is performed, the flag temperature is measured together with the video level. This process is anyhow performed every few minutes due to NUC instability; consequently, a very stable radiometric operating point is achieved. The internal temperature reference source is sampled at a higher rate than the temperature fluctuation time constant.

   b. b. The impulse response of any cameras has a general two dimensional low pass filter shape. An inverse filter to the camera impulse response, which has a general behavior of high pass response, is used to compensate the radiometer modulation transfer function response.

Field of the invention

This invention relates to the capability of using simple FLIR cameras based on uncooled microbolometer detectors to measure temperature. A simple uncooled microbolometer detector that does not contain any radiation shield is used in order to build an accurate radiometer. The infrared radiation of the scenery observed by the FLIR camera is translated to a two dimensional array of temperatures.

1

Background of the invention

The invention describes a simple method that enables to use the already existing "flag" in order to obtain a stable and accurate temperature reference. The less expensive vacuum packages for uncooled microbolometer detectors do not contain any radiation shield. The average value, and the very low frequency components, of the video signal obtained from the detector after the processes of non-uniformity correction (NUC) and bad pixels replacement (BPR) are drastically influenced by the temperature of the detector's vacuum package and internal camera parts. In order to be able to translate into temperature the video signal after NUC and BPR processes, an independent temperature reference source has to be used. The independent temperature source is used in order to correlate between the reference source temperature and the video signal obtained for this specific reference temperature. During the short period of time while the detector field of view (FOV) is covered by the temperature source, the value of the video signal after NUC and BPR is measured and stored as a reference matrix. While the detector is open to the scenery a differential signal measurement is performed against the reference matrix. The differential video signal is translated to temperature values and the known temperature of the reference source is the offset vale to be added in order to obtain the real temperature and not the differential one. The reference matrix acquisition has to be performed periodically in order to limit the drift of the video signal below a given threshold value dictated by the temperature measurement accuracy required.

A direct translation of the differential video signal into temperature is relative accurate only for large objects. More specific the translation of the video signal into temperature is subjected to the error introduced by the limited modulation transfer function (MTF) response for high spatial frequencies. In order to overcome this error an inverse filter of camera MTF is used. The general response of camera inverse filter is a two dimensional high pass filter (HPF).

Detailed description

The Temperature Reference Source

1. A mechanism that contains one ore several metal (or other materials) sheet or sheets so called "flag mechanism". The metal (or other materials) sheet or sheets is the so called "flag".
2. Located between:
2.1 The detector and the optics or,
2.2 In front of the optics,
3. That has two stable mechanical positions:
3.1.1 One that the flag covers the entire detector's field of view case 2.1 or,
3.1.2 That the flag covers the entire optics field of view case 2.2,
3.2.1 A second position that does not cause any obscuration or partial obscuration to the detector's field of view in case of 2.1 or,
3.2.2 A second position that does not cause any obscuration or partial obscuration to the optics field of view

2

4. The flag surface seen by the detector has :

4.1 Either an emissivity that equals 1, ore close to one, for the spectral band in which the detector is sensitive to the electromagnetic spectra radiation, or

4.2 A reflectivity that equals one, or close to one, for the spectral band in which the detector is sensitive to the electromagnetic spectra radiation,

5. The flag surface seen by the detector in case of 4.1, has a known temperature at any time, in case of 4.1 . The temperature can be obtained:

5.1. by direct contact measurement using a sensor located on the back of the surface seen by the detector, in case of 4.1 or

5.1.2 by measuring the radiation emitted by the flag surface seen by the detector, in case of 4.1

5.2 The temperature seen by the detector in case of 4.2, reflected by the flag surface seen by the detector in case of 4.2, is its own temperature.

6. The flag mechanism is oscillating between positions 3.1 and 3.2 staying short periods of time in position 3.1 and long periods of time in position 3.2 .

7. While flag mechanism is in stable position 3.1 , the detector's signal after non uniformity correction and bad pixels replacement is collected and stored in a reference matrix. Usually this reference matrix will be obtained by averaging a large number of detector's frames in order to reduce the temporary noise.

$$\text{Re ference\_matrix}_{i,j} = \frac{1}{N} \sum_{K=1}^{N} p_{i,j,K}$$

i represents one matrix dimension
j represents the orthogonal direction to I
k represents a dummy variable of different frames in time, acquired while the detector field of view is blocked by the flag.

$p_{i,j,K}$ represents the video signal of frame number k after non uniformity correction and bad pixels replacement.

During the same period of time that the reference matrix is acquired the so called "reference temperature" is measured:

7.1 in case of 4.1 the temperature of the flag is measured, or

7.2 In case of 4.2 the detector temperature is measured.

8. While flag mechanism is in position 3.2 the temperature at any point in the detector field of view is calculated using the following general expression:

$T_{i,j}$ = F ($p_{i,j}$ - Re ference_matrix$_{i,j}$, $E_{i,j}$, temp_amb , etc)+ Reference_temperature

Reference_temperature represents the reference temperature defined in 7 .

$T_{i,j}$ represents the temperature value associated to each one of $p_{i,j}$ video signal element value.

$p_{i,j}$ represents the video signal of element i,j after non uniformity correction and bad pixels replacement or

$p_{i,j}$ represents the video signal of element i,j after non uniformity correction bad pixels replacement and MTF inverse filter.

$E_{i,j}$ represents the emissivity of the surface seen by the detector at location i,j.

temp_amb represents the ambient temperature around the seen scenery.

F(...) represents a general function that translates the detector video signal into temperature using different input variables like the video signal, the reference matrix, the emissivity, the ambient temperature etc.

The MTF Inverse Filter

9.   A two dimensional high pass filter that is an accurate or an approximation of the system modulation transfer function inverse transform, so called inverse filter.

10. The video signal is passed through the inverse filter before the general transform described in 8 is performed.

Figures

Reference is now made to the appended figures. Fig. 1 is a graph illustrating an MTF inverse filter. Figs. 2 and 3 are views of FLIR cameras based on uncooled microbolometer detectors which can be used in the present invention to measure temperature

Claims:

1. Apparatus for measuring temperature comprising at least one FLIR cameras based on uncooled microbolometer detectors, substantially as hereinbefore described with respect to the accompanying drawings.

2. Apparatus according to claim 1, further comprising an internal temperature reference source.

3. Apparatus according to claim 1, further comprising multiple use of a flag mechanism.

4. Apparatus according to claim 1, further comprising an inverse modulation transfer function filter

5. Method for measuring temperature using a FLIR camera based on uncooled microbolometer detectors, substantially as hereinbefore described with reference to the accompanying drawings.

Geoffrey Lionel Melnick
Patent Attorney
G. E. Ehrlich (1995) Ltd.
11, Menachem Begin Street
52521 Ramat-Gan

5

OPGAL LTD.

Frequency Response
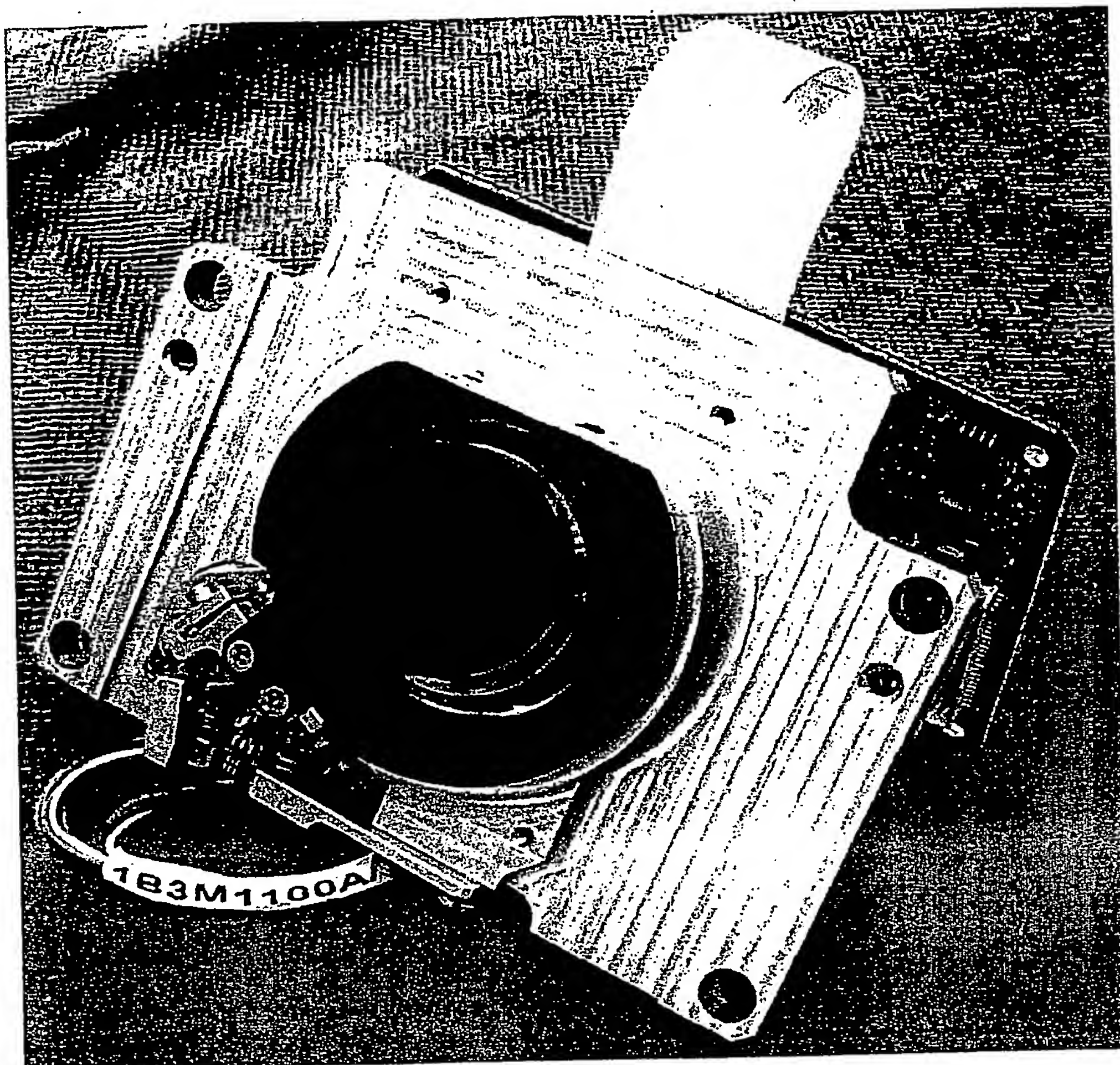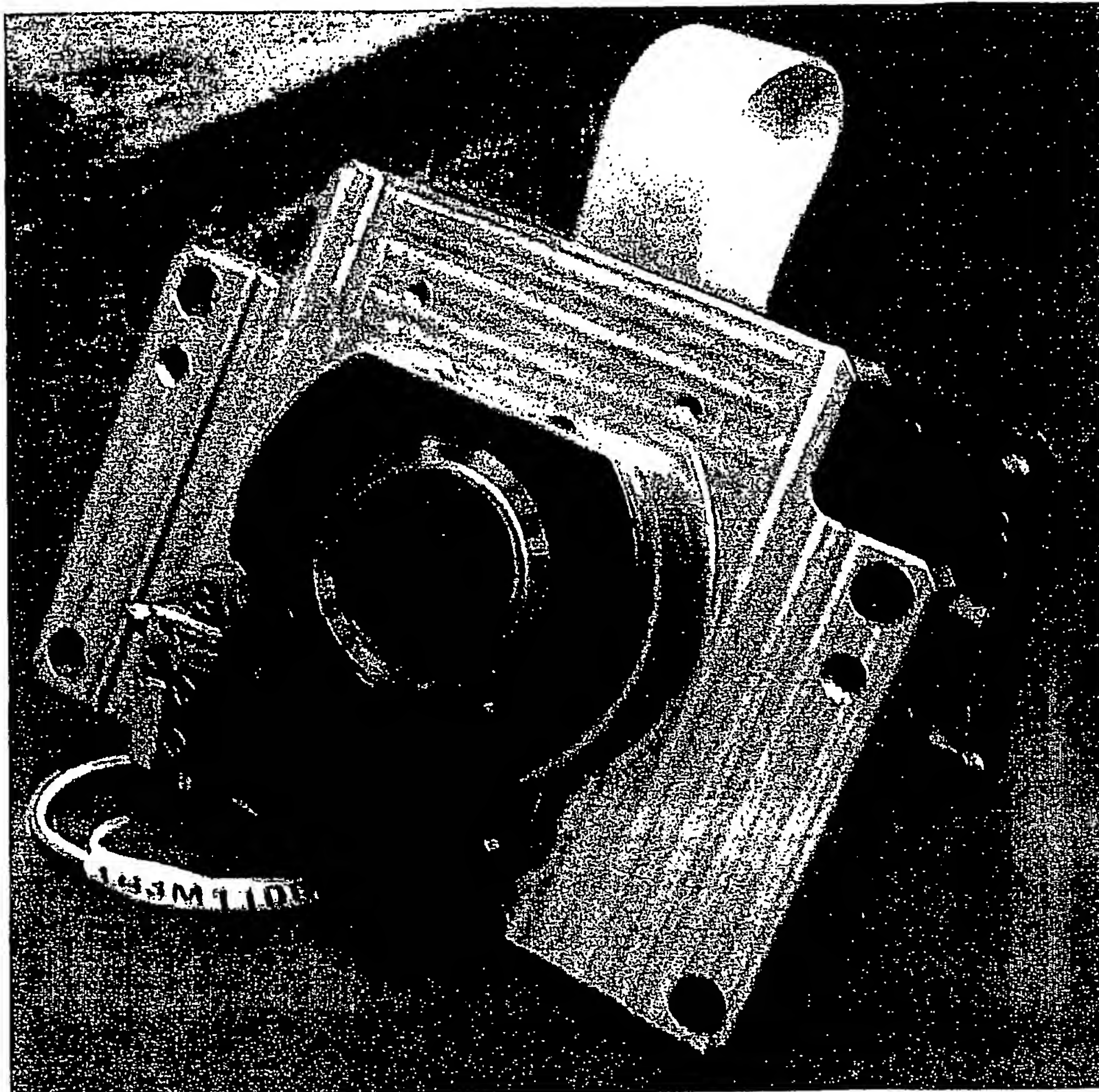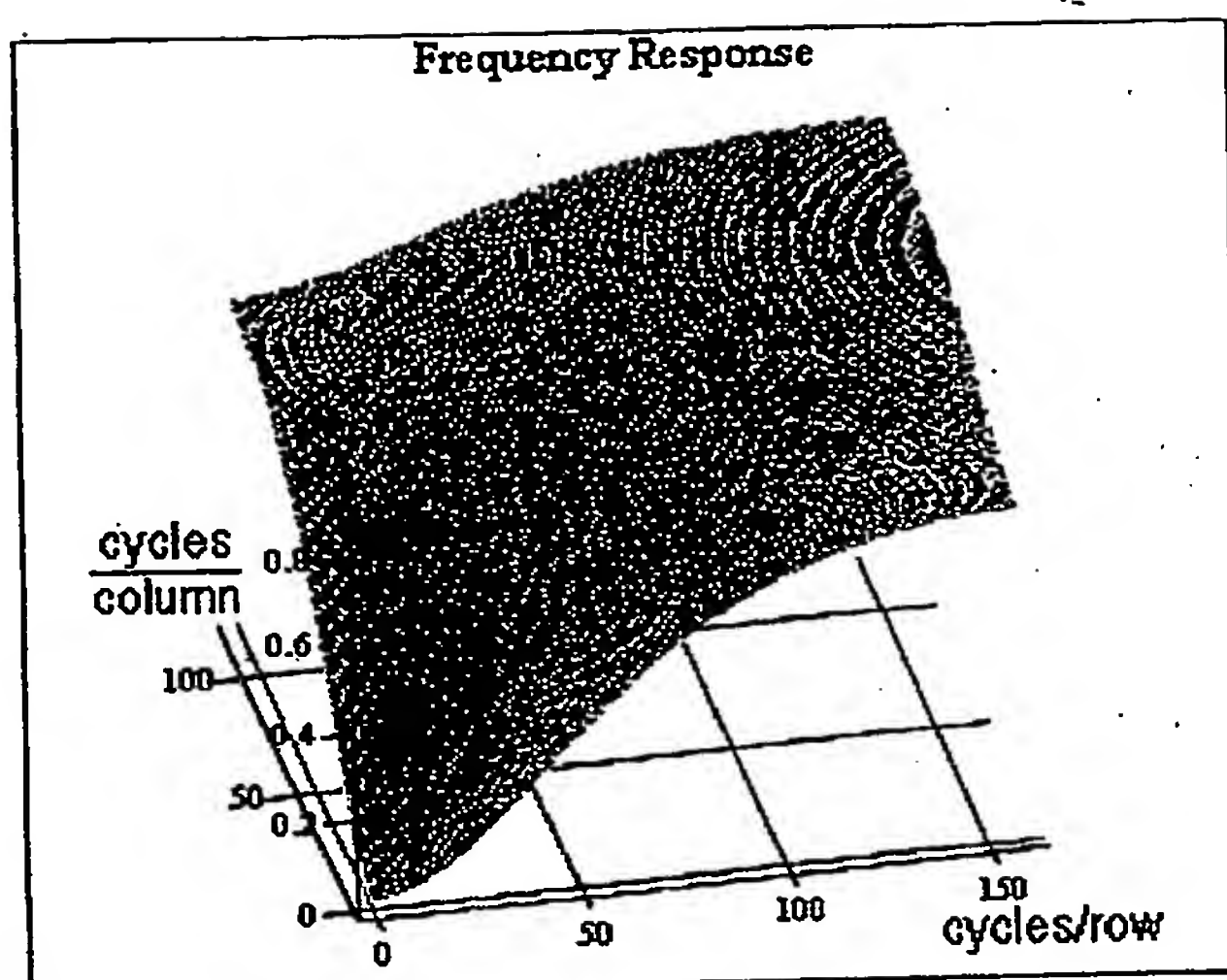
High Pass Filter Frequency Response. This filter is the MTF inverse approximation for a detector that contains 320 by 240 elements.